ABSTRACT AND REFERENCES

ENGINEERING TECHNOLOGICAL SYSTEMS

DOI: 10.15587/1729-4061.2017.114433

DEVELOPMENT OF THE CRITERION AND THE METHOD OF ESTIMATION OF THE COMPLEXITY OF THE STRUCTURE OF TECHNOLOGICAL SYSTEMS (p. 4–11)

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In the process of designing, manufacturing and operating complex technological systems, it is necessary to have criteria and methods for assessing the perfection of their structure. A method for assessing the complexity of the structure of technological systems by the criterion that is a complex quantity and takes into account the number of system elements, connections between elements, connections between elements and the external environment, and the hierarchical level of elements in the system is developed. The choice of the criterion was made under the following assumptions: the element of the system has one «input» and one «output», through which its interaction with other elements of the system and the external environment occurs; the state of the system element is uniquely determined by the state of its «input». The complexity of the structure of the unit element is unity; the complexity of the structure of the system consisting of an infinite number of elements is equal to infinity. The complexity of the system structure is determined by the number of system elements, the number of connections between them and the external environment, and also the hierarchical level of the element in the system. The method for assessing the complexity of the structure of technological systems is sufficiently accurate, intuitively acceptable and suitable for practical research. Application of the developed method in practice allows solving the problem of objective analysis of the structure of complex technological systems and giving them a quantitative assessment. An example of using the method for analyzing the structure of technological equipment systems of sintering plants of the Krivoy Rog iron ore basin (Ukraine) is given.

Keywords: technological systems and elements, structure of technological systems, criterion of complexity of the structure of technological systems.

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DOI: 10.15587/1729-4061.2017.118961

ANALYSIS OF THE FORMATION OF FILAMENT WINDING IN TERMS OF FORCE INTERACTIONS BETWEEN THREADS (p. 11–18)

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We investigated a problem of filament winding formation in terms of force interactions between threads. It was established that at certain ratios between the frequency of bobbin rotation and the frequency of thread feeder motion the threads are laid on the same place. This results in the formation of the so-called filament winding. In this case, in an extreme case, a turn of the thread is laid exactly on the place of the preceding one. This phenomenon, however, occurs only if the thread is considered ideal, that is, it has no thickness. It is shown that due to sufficient complexity of actual processes a thread cannot be placed exactly on the place of the one laid earlier, which results in that it flies off it. In this case, the turn laid earlier acquires the role of a spreader, that is, it defines the place of laying a thread on the bale. This place can differ significantly from that set by the motion of a thread feeder, resulting in the formation of chords, which cause breaks of thread at subsequent unwinding of the bobbin.

It is proposed, in order to eliminate the specified defects of winding in the form of filaments and chords that accompany them, to reduce to the permissible minimum the distance from the eye of a thread feeder to the point of attack. We describe conditions under which a fly-off of the turn occurs, based on which it becomes possible to determine the number of turns, laid with a breach of the kinematic conditions, as one of the basic parameters of the process. The latter means that there is no need for the thread feeder to control it. It is shown that a given parameter depends on the inclination angle of the turn, and the application of the resulting analytical description of this relation does not present any practical difficulties because all actual values of its constituent magnitudes, except for thread twisting stiffness, are known when designing a winding mechanism.

It was established that in addition to the proposed design solution it is necessary to maintain the tension not less than 20 sN for the yarn 225×2 tex. In the case of other linear densities, this parameter can be calculated based on the obtained analytical dependences for a thread inclination angle and duration of torsional oscillations of a homogeneous rod suspended in the middle. Such results form the basis of requirements to the design of a winding mechanism, which are aimed at reducing the number of uncontrollably placed turns.

Keywords: filament winding, chord, thread feeder, defects in winding, point of attack.

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DOI: 10.15587/1729-4061.2017.118276

STUDY OF THE PROCESS OF GRAIN PRE-THRESHING BY WORKING BODIES OF A COMBINE HARVESTER HEADER (p. 19–27)

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We improved the combined technological process of transportation and threshing of GSM and developed the device of preliminary grain threshing for a grain header of KZS 9-1 «Stavutich» harvester, which made it possible to separate 30–35 % of grain at the early phases of its transportation to TSS of a combine. We established that the coefficient of separation of grain from cones in a header with an intermediate thrashing drum, which contains four additional tooth-shaped bars of 30 mm in height, has the highest (0.32) value.

We developed a calculation and experimental method for determining the amount (degree) of grain separation by a device of a header of a combine harvester. The method is based on the results of simulation of the combined process of transportation and threshing of grain caused by the interaction of a drum with grain and straw mass.

We analyzed and proved the complex influence of structural parameters of the device and modes of implementation of the combined process of transportation and threshing of GSM at the level of separation of grain. And this make it possible to establish a theoretical dependence of the grain separation coefficient. The noted theoretical dependence provides the possibility to substantiate rational parameters and operating modes of the device of preliminary grain threshing of a combine harvester analytically.

We determined dependences of the grain separation coefficient on the speed of a combine experimentally. The dependences take into account cancellations of mechanized technological operations caused by changes in kinematic operating modes of a combine, a number of stops and their height on a drum of a device of preliminary grain threshing.

Keywords: grain combine harvester, header, device for preliminary grain threshing, grain separation coefficient, mass of separated grain.

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DOI: 10.15587/1729-4061.2017.118731

INVESTIGATION OF VIBRATION MACHINE MOVEMENT WITH A MULTIMODE OSCILLATION SPECTRUM (p. 28–36)

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The necessity of solving the problem of increasing the efficiency and reducing the energy intensity of the working process of the vibration machine movement is substantiated. A new principle is proposed for transferring energy from the shape-forming surfaces to the processing medium by implementing highly effective modes and parameters. A constructive scheme and a definite mathematical model of the frame of the vibration machine have been developed, realizing complex spatial oscillations. The oscillations of this shape-forming surface are investigated using the finite element method. The finite element model is composed by approximating all load-bearing elements of the frame with beam end elements. Loads created by pneumatic centrifugal exciters of high-frequency oscillations are determined. The basic waveforms of the shape-forming surfaces that are realized at 18.79 Hz, 18.89 Hz and 19.71 Hz, respectively, are investigated and determined. The distribution of the vibration amplitudes along the perimeter of the frame is estimated at the excitation frequency of 182.5 Hz. The rational values of the amplitude of oscillations for the realization of an effective process of concrete mixture compaction are found. The amplitude of the oscillations is 0.0002...0.0005 m. The obtained vibrations show the presence of the multimode operation of the vibration machine. A definite direction of the purposeful use of one of the forms of natural oscillations is the shape-forming surfaces. The approach for creating high-performance vibration machines of a new generation is proposed. The ideology of implementing such regimes can be successfully applied in road construction for the construction of concrete roads.

Keywords: vibration machine, vibration exciter, spatial oscillations, stress-strain state, frequencies and vibration modes, finite element model.

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DOI: 10.15587/1729-4061.2017.115019

INFLUENCE OF THE TECHNICAL CONDITION OF THE RUNNING GEAR OF A TRUCK TRACTOR AND A SEMI-TRAILER ON THE FUEL EFFICIENCY OF THE TRACTOR-TRAILER TRUCK (p. 37–43)

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The research revealed that rolling of wheels of misaligned semi-trailers axles is identical to rolling of slip wheels under the influence of lateral forces, which leads to a discrepancy between the rotation and rolling planes of the wheel. As a result, there are additional lateral and longitudinal forces and increased rolling losses, and as a consequence, the tractor-trailer truck performance, in particular, fuel efficiency, deteriorates. Note that even with the same technical condition of the running gear of the truck tractor and the semi-trailer during their manufacture, different degrees of wear of tires, suspension elements of axles of the truck tractor and the semi-trailer can be revealed after a certain period of operation, as the wear rate depends on axle angles, wheel load, lateral forces, tangential forces (traction and braking) and air pressure in tires. In quantitative terms, these factors are not identical for each axle of the tractor-trailer truck. So, if there are different axle angles and different wear rates of the tread, it is possible to speak about changes in the rolling resistance and fuel consumption of the tractor-trailer truck.

Thus, in case of misalignment of one semi-trailer axle by 0.57 degrees, the rolling resistance coefficient increases by 12 %; by 1.25 degrees – 17.8 %; by 2.11 degrees – 26.2 %. An increase in the rolling resistance coefficient leads to the growth of fuel consumption. As an example, it was shown that in the highway driving cycle of the tractor-trailer truck, an increase in the rolling resistance coefficient is doubled from 0.01 to 0.02, fuel consumption in the cycle increases by 43 %, and under the three-time change from 0.01 to 0.03 – by 95 %. This necessitates the design and research works aimed at reducing the axle misalignment of semi-trailers and tractors in the process of manufacture and operation.

Keywords: truck tractor, tractor-trailer truck, semi-trailer, fuel efficiency, running gear, axle angles.

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DOI: 10.15587/1729-4061.2017.116317

ESTIMATION OF THE ADAPTABILITY OF AUTOMOBILES TO OPERATION UNDER WINTER CONDITIONS BASED ON THE ENGINE COOLING RATE (p. 44–50)

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In the course of the present study we devised an indicator of the adaptability of automobiles to operation under winter conditions based on the engine cooling rate, and a procedure of its estimation. A three-level grading assessment of the adaptability of automobiles to operation under winter conditions based on the engine cooling rate is proposed. We established an exponential form of the mathematical model for a change in the engine cooling rate, which takes into consideration speed of the wind that blows over the engine, its mass and heat insulation, as well as arrangement density in the under-hood space.

Numerical values for the parameters of the mathematical model were determined.

Results of the research allow us to estimate the limits of operational conditions of the rational use of automobiles when cooling rate of an idle engine does not exceed the critical value, and, therefore, fuel consumption used by the engine to maintain a temperature mode under given operating conditions during a short stop is minimal.

Keywords: winter operating conditions; automobile engine cooling; cooling rate, vehicle adaptability.

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DOI: 10.15587/1729-4061.2017.116085

STUDY OF ENERGY EFFICIENCY OF THE PROCESSES OF MECHANICAL DESTRUCTION OF WORN AUTOMOBILE TIRES (p. 51–60)

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We studied the process of cutting the worn pneumatic Bridgestone tire the size of 7.1/11.0-5 using the cutting tool made of alloys of grades R6M5 and T15K6, resulting in the obtained data array on the reduced cutting forces. Regression coefficients were calculated, which formed the basis of a mathematical model in the form of a second-order polynomial. The constructed mathematical model expresses cutting forces dependence on the totality of geometrical parameters and hardness of the cutting tool's material and operational parameters of the cutting process. Using it can help determine the combination of optimal geometrical parameters, material of the cutting tool and operational parameters in order to ensure the minimization of cutting forces and energy consumption for the cutting process as a whole.

The mathematical model was refined based on the obtained equation of cutting force dependences on tensile strength of the materials of automobile tires. The adequacy of the refined model was confirmed by estimating homogeneity of variances of the estimated and experimental values of cutting forces by using a statistical Fischer criterion. We determined effective operational parameters: spindle rotation frequency and cutting tool feed; geometrical parameters and hardness of the cutting tool's material, which ensure minimal power consumption when cutting worn automobile tires.

Keywords: cutting tires, cutting tool, cutting forces, mathematical model, energy efficiency, optimization.

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DOI: 10.15587/1729-4061.2017.114564

INVESTIGATION OF THE PROCESS OF THREAD EXTRUSION USING THE ULTRASOUND (p. 60–68)

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We investigated and modelled the process of ultrasonic extrusion of a thread when imposing the ultrasonic oscillations. Based on the rheological model of deformation of the perfect elastic-plastic body, we constructed dependences for the calculation of contact pressures and specific friction force. In carrying out the present research, in order to simplify a mathematical model, the assumption was made on that the phenomenon of surface strengthening exerts little effect on the magnitude of contact pressure and friction force at plastic deformation.

This mathematical model describes complex motion of the tool (rotational and oscillatory motion of the tap). The system of the derived dependences, which describes the influence of oscillation amplitude, oscillation direction, deformation rate, and mechanical properties of the machined material on the magnitude of contact pressure, makes it possible to estimate parameters of the process of plastic deformation when imposing the ultrasound. By employing such a description, it is possible to derive the value of contact pressure and friction forces for each region of the load chart.

During analysis of the obtained results it was established that an increase in the amplitude of oscillations leads to a decrease in the time of contact between a tool and the machined surface, which is why contact pressure, specific friction of axial and torsional oscillations over a period decrease accordingly within a change in the examined factors.

The benefit of the present study is a detailed analysis of the contact interaction between a tool and a part, as well as consideration of mechanical properties of the machined material, which makes it possible to choose the modes of treatment and to provide maximum operational performance.

Keywords: ultrasonic thread extrusion, oscillation amplitude, contact pressure.

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DOI: 10.15587/1729-4061.2017.118006

EFFECT OF MICROWAVE DRYING OF THE SPINES OF BOOK BLOCKS ON THE QUALITY OF PRINTED MATERIALS (p. 68–79)

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Based on the main provisions of the theory of heat and mass transfer, we examined the kinetics of natural and microwave drying of the spines of book blocks. The existence of three periods of drying is proven: a period of warming the block (when the moisture content of paper reduces along a certain curve); a period of constant rate (when moisture content reduces by the law of a straight line); a period of falling rate (when there is a redistribution of moisture removal and it becomes uniform for all layers, thereby ensuring product quality).

Based on the graph-analytic analysis of curves of the intensity of microwave drying and mathematical modeling, we demonstrated relationship between the time of drying, temperature, and the type of paper. Thus, an increase in relative air humidity by 20 % results in a decrease in the intensity of drying by about 2 times (for the blocks made from chalk overlay paper) and by 1.5 times (for the blocks made from offset paper). An increase in air temperature by 10 °C results in a reduction in the drying time of blocks made from chalk overlay paper by about 1.5 minutes, and of the blocks made from offset paper – by 1 minute. We established optimal modes of microwave drying of book blocks (3–5 minutes at a temperature of 40 °C).

We have proven a positive effect of microwave drying on the performance indicators of books: resistance of blocks to the sign-alternating loads on the spine, maximal effort of breaking the blocks and pulling sheets out of the blocks. The study that we conducted is important to ensure quality in the book manufacturing process, as well as strength of book structure for its intensive use by readers.

Keywords: spines of book blocks, glued joints, microwave drying, quality of printed materials.

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